

WHAT IS CLAIMED IS:

1 1. A digital to analog converter system, comprising:
 2 a multi-bit digital to analog converter (“DAC”) to (i) receive a digital input signal
 3 having a frequency attenuation band around a frequency f_{chop} , and (ii)
 4 convert the DAC input signal into a representative analog signal, the DAC
 5 comprising:
 6 a modulation circuit having a modulation frequency of f_{chop} to modulate
 7 the DAC input signal by f_{chop} ;
 8 a gain stage coupled to the modulation circuit to receive signals modulated
 9 by the modulation circuit and provide gain for the DAC, wherein
 10 during operation the gain stage is associated with noise having
 11 frequencies within the baseband; and
 12 a demodulation circuit, coupled to the gain stage and having a
 13 demodulation frequency equal to approximately or equal to f_{chop} , to
 14 demodulate signals by approximately or equal to f_{chop} ; and
 15 a notch filter to generate the frequency attenuation band around the frequency f_{chop}
 16 to reduce introduction of noise into a frequency baseband of the digital
 17 input signal.

1 2. The digital to analog converter system of claim 1 wherein the digital input
 2 signal further includes a frequency attenuation band around a frequency $2f_{chop}$, the system
 3 further comprising:
 4 a notch filter to generate the frequency attenuation band around the frequency
 5 $2f_{chop}$ to further reduce introduction of noise into the frequency baseband
 6 of the digital input signal.

1 3. The digital to analog converter system of claim 1 wherein the notch filter
 2 includes a frequency attenuation band equal to or greater than the baseband and centered
 3 at approximately or equal to f_{chop} .

1 4. The digital to analog converter system of claim 1 wherein the notch filter
2 is a digital finite impulse response filter coupled to an input of the DAC and implemented
3 using hardware components.

1 5. The digital to analog converter system of claim 1 wherein the DAC
2 comprises a switched capacitor digital to analog converter.

1 6. The digital to analog converter system of claim 5 wherein the switched
2 capacitor digital to analog converter includes sampling capacitors to receive charge
3 representative of the DAC input signal, a feed back capacitor, and switches to share
4 charge between the sampling capacitors and the feed back capacitor.

1 7. The digital to analog converter system of claim 1 wherein the modulation
2 circuit is a chopping modulator comprising series and cross-over switches to chop input
3 signals of the gain stage, the demodulation circuit is a chopping circuit comprising series
4 and cross-over switches to chop output signals of the gain stage, and the gain stage is a
5 component of a fully differential amplifier.

1 8. The digital to analog converter system of claim 1 further comprising:
2 a modulator, coupled to the DAC, to receive a first digital input signal sampled at
3 a frequency, f_s , to modulate the digital input signal, wherein the first
4 digital input signal includes frequency components residing within the
5 baseband bounded by frequencies f_1 and f_2 and wherein a byproduct of the
6 first digital input signal modulation includes quantization noise having
7 frequency components residing outside of the baseband, wherein the input
8 signal of the DAC is derived from the modulated first digital input signal.

1 9. The digital to analog converter system of claim 8 wherein the notch filter
2 is implemented within the modulator.

1 10. The digital to analog converter system of claim 8 wherein the modulator is
2 a delta sigma modulator and the notch filter is implemented within an internal feedback
3 path of the delta sigma modulator.

1 11. The digital to analog converter system of claim 8 wherein f_1 and f_2 define
2 respective high and low frequencies of an audio signal baseband.

1 12. The digital to analog converter system of claim 10 wherein $f_1 = 0$ Hz and f_2
2 = 25 kHz.

1 13. A method to attenuate chopping noise of a digital to analog converter
2 within a frequency baseband of an input signal, wherein the chopping noise is associated
3 with a chopping circuit having a chopping frequency of f_{chop} , the method comprising:
4 attenuating noise signal components of an input signal modulated by a multi-bit
5 digital to analog converter prior to chopping over an attenuation band at
6 least equal to the baseband of the input signal and centered at f_{chop} ,
7 wherein f_{chop} is greater than a highest frequency of the baseband of the
8 input signal.

1 14. The method as in claim 13 further comprising:
2 attenuating noise signal components of the input signal prior to chopping over an
3 attenuation band at least equal to the baseband of the input signal and centered at $2f_{chop}$.

1 15. The method as in claim 13 wherein attenuating signal components
2 comprises:
3 filtering the digital input signal using a digital finite input response notch filter.

1 16. The method as in claim 13 further comprising:
 2 modulating the digital input signal comprises modulating the digital input signal
 3 using a delta sigma modulator; and
 4 wherein attenuating signal components comprises filtering the modulated digital
 5 signal further comprises filtering the modulated digital input signal within
 6 a feedback loop of the delta sigma modulator.

1 17. The method as in claim 13 wherein the digital input signal is an audio
 2 signal.

1 18. A method to attenuate chopping noise of a digital to analog converter
 2 within a frequency baseband of an input signal, wherein the chopping noise is associated
 3 with a chopping circuit having a chopping frequency of f_{chop} , the method comprising:
 4 attenuating noise signal components of a digital input signal within a loop of a
 5 delta-sigma modulator prior to chopping over an attenuation band at least
 6 equal to the baseband of the input signal and centered at f_{chop} , wherein f_{chop}
 7 is greater than a highest frequency of the baseband of the input signal to
 8 reduce introduction of noise into a frequency baseband of the digital input
 9 signal.

1 19. The method as in claim 18 further comprising:
 2 attenuating noise signal components of a digital input signal within a loop of the
 3 delta-sigma modulator prior to chopping over an attenuation band at least
 4 equal to the baseband of the input signal and centered at $2f_{chop}$ to further
 5 reduce introduction of noise into a frequency baseband of the digital input
 6 signal.

1 20. An audio system comprising:
 2 a digital audio signal source;

3 a digital to analog converter (“DAC”) to (i) receive a digital input signal from the
 4 digital audio signal source having a frequency attenuation band around a
 5 frequency f_{chop} , and (ii) convert the DAC input signal into a representative
 6 analog signal, the DAC comprising:
 7 a delta-sigma modulator having a notch filter within the delta-sigma
 8 modulator to generate the frequency attenuation band around the
 9 frequency f_{chop} to reduce introduction of noise into a frequency
 10 baseband of the digital input signal;
 11 a modulation circuit having a modulation frequency of f_{chop} to modulate
 12 the DAC input signal by f_{chop} ;
 13 a gain stage coupled to the first modulation circuit to receive signals
 14 modulated by the modulation circuit and provide gain for the
 15 DAC, wherein during operation the gain stage is associated with
 16 noise having frequencies within the baseband; and
 17 a demodulation circuit, coupled to the gain stage and having a
 18 demodulation frequency equal to approximately or equal to f_{chop} , to
 19 demodulate signals by approximately or equal to f_{chop} ;
 20 an amplifier coupled to the DAC; and
 21 an audio output device coupled to the DAC.

1 21. The audio system of claim 20 wherein the digital input signal further
 2 includes a frequency attenuation band around a frequency $2f_{chop}$, the system further
 3 comprising:
 4 a second notch filter within the delta-sigma modulator to generate the frequency
 5 attenuation band around the frequency $2f_{chop}$ to further reduce introduction
 6 of noise into the frequency baseband of the digital input signal.

1 22. The audio system of claim 20 wherein the modulation circuit is a chopping
 2 modulator comprising series and cross-over switches to chop input signals of the gain
 3 stage, the demodulation circuit is a chopping circuit comprising series and cross-over

4 switches to chop output signals of the gain stage, and the gain stage is a component of a
5 fully differential amplifier.

1 23. The audio system of claim 20 wherein the notch filter includes a frequency
2 attenuation band equal to or greater than the baseband and centered at approximately or
3 equal to f_{chop} .

1 24. The audio system of claim 20 wherein the notch filter is a digital finite
2 impulse response filter.